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AIR POLLUTION LEVELS AND REGULATIONS IN THE FEDERAL REPUBLIC OF GERMANY

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ARGONNE NATIONAL LABORATORY
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by

Marshall Monarch

Energy and Environmental Systems Division
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FOREWORD

This report is one of a series of three prepared for the Office of Fossil Energy (OFE) of the U.S. Department of Energy. Each report deals with one country in which acid deposition, commonly referred to as acid rain, has been a prominent issue of public discussion. The three countries covered in this series of reports are Canada, the Federal Republic of Germany, and the United Kingdom. For each country, air pollution control regulations and trends in air quality and emissions are broadly outlined, then are compared with corresponding regulations and trends in the United States. Since acid rain is the intended field of application, the reports generally deal only with sulfur dioxide, nitrogen oxides, ozone, and total suspended particulates. Carbon monoxide has not been covered, as it is not emitted in significant quantities by the stationary combustors of fossil fuels of interest to OFE. The primary purpose of these reports is to supply reasonable comparisons and information to OFE personnel involved in policy development and speech preparation.

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1 AIR POLLUTION LEGISLATION AND REGULATIONS

1.1 FEDERAL IMMISSION CONTROL LAW

Air pollution in the Federal Republic of Germany (FRG) is primarily regulated under the Federal Immission Control Law of March 15, 1974 (amended in 1978 and 1983).* This law also regulates noise, vibrations, and similar phenomena. Its objectives are to protect people, animals, plants, and commodities from detrimental environmental impacts and to prevent these detrimental effects from the outset. As stated by P. Beck of the FRG Federal Environmental Agency, "the declared aim of the German air pollution control policy is to reduce total exposure to air pollutants . . . and to maintain the existing air quality in areas with relatively clean air."[1] The law applies to both stationary and mobile sources.[2]

To achieve these air pollution control objectives, the Federal Immission Control Law provides for limitations on both emissions and immissions. These limits are to be applied independently of each other. Immission loads resulting from source emissions are evaluated as to their impact on ambient air quality. Tolerable immission loads are defined such that they are not exceeded when new installations are constructed or existing installations are extended at the same plant. Emission limitations are based on the principle of "anticipatory action," which permits control measures to be implemented for the purpose of preventing possible future consequences, even though such measures may not be deemed immediately necessary or whose indispensable nature in providing protection against harmful environmental effects is still being debated. Requirements for use of the state-of-the-art, or "best available," emission control technology are justified under this principle. Both immission and emission limitation strategies are implemented on a case-by-case basis by installation, area, and product-related measures.

A set of regulations under the Federal Immission Control Act was issued by the federal government in 1983, entitled *Technical Instruction for the Protection of Air Purity* (known as TA Luft). The TA Luft establishes air quality and emission standards and regulates the height of smokestacks and the characteristics of monitoring instrumentation.

Enforcement of the Federal Immission Control Act and regulations promulgated under it, including the TA Luft and the First General Administration regulations, is the

*Relative to air pollution, immission is defined as an emission-induced change in the concentration of pollutants in the atmosphere.

task of the states within the Federal Republic. The states' environmental protection duties include licensing. For example, any industrial installation that might produce pollutants or, more generally, harmful effects must obtain a construction and operating license. The TA Luft enumerates 98 classes of industrial processes that require such a license. A permit can be granted if pollution control devices corresponding to the best practicable or available control technology have been installed.[3] In the FRG, the concept of "best available control technology" refers to the most advanced processes, installations, and/or methods of operation that have proven, in full-scale operation,* to be appropriate for reducing emissions. Determinations are made on a case-by-case basis, taking into account such factors as the control technology's effectiveness, reliability, and safety in operation, its cost and maintenance needs, variable-load factors, energy demand, the expected lifetime of the facility, and the production of other pollutants (including transmedia pollutant effects). The final requirement may not always be the technology with the highest rate of emission control but, rather, an overall optimum based on all of the relevant factors.[4,5]

The states may designate for special protection areas that are of particular beauty, are dedicated to recreational use, or are subject to special meteorological conditions or forms of pollution. On the basis of these provisions, several states have approved air pollution laws for specific areas. These laws establish that officials may impose special restraints on operation when conditions, for example, of air stagnation or inversion arise or when certain air pollution levels have been reached.

To guarantee compliance with the Federal Immission Control Law, each operator of a licensed installation must appoint an immission control officer, who is responsible, however, to the operator, not to any public authority. The officer must ensure compliance with all pertinent related regulations and license conditions. This task involves regular inspections and monitoring of immissions and emissions.

1.2 AMBIENT AIR QUALITY STANDARDS

The TA Luft of 1983 established ambient air quality (i.e., immission) standards, which are summarized in Table 1.1. The FRG air quality standards are expressed in micrograms per normal cubic meter ($\mu g/Nm^3$). The normal cubic meter is a measure of gas volume at 1 bar pressure and 15°C. The FRG long-term standard is an annual mean value, while the short-term standard is established as the 95th percentile of daily mean values, which thus allows 5% of the daily mean values to equal or exceed the short-term standard. Ambient air quality standards in the United States consist of two levels: primary, which are defined as health-related, and secondary, defined as welfare-related.

As shown in Table 1.1, the FRG long- and short-term ambient air quality standards are less stringent than the corresponding U.S. Environmental Protection Agency (EPA) standards except for nitrogen dioxide (NO_2). The FRG long-term standard

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*Pilot-plant operation does not necessarily qualify a control technology as being the "best available."

TABLE 1.1 FRG and U.S. Ambient Air Quality Standards (μg/m³ except where noted)

Pollutant	Long-Term Standard			Short-Term Standard		
		United States			United States	
	FRG[a]	Primary	Secondary	FRG[b]	Primary	Secondary
Sulfur dioxide	140, 60[c]	80[a]	-	400	365[d]	1300[e]
Total suspended particulates	150	75[f]	60[f,g]	300	260[d]	150[d]
Particulates ≤ 10 μm	100	-	-	200	-	-
Nitrogen dioxide	80	100[a]	-	300	-	-
Nitrogen monoxide	200	-	-	600	-	-
Ozone	-	-	-	-	235[h]	-
Carbon monoxide[i]	10	-	-	30	10,[j] 40[k]	-
Lead	-	1.5[l]	-	-	-	-

[a]Annual arithmetic mean.

[b]95th percentile of daily mean values.

[c]For pristine regions where the 60-μg/m³ level was not exceeded in 1983.

[d]24-h arithmetic mean.

[e]3-h arithmetic mean.

[f]Annual geometric mean.

[g]This annual geometric mean is a guide to be used in assessing implementation plans to achieve the 24-h standard of 150 μg/m³.

[h]Maximum daily 1-h average not to be exceeded more than once a year.

[i]All values given in milligrams per cubic meter (mg/m³).

[j]8-h arithmetic mean not to be exceeded more than once a year.

[k]Maximum 1-h value not to be exceeded more than once a year.

[l]Maximum quarterly average.

Source: Ref. 5.

for NO_2 is 80 $\mu g/m^3$, compared with the EPA standard of 100 $\mu g/m^3$. The FRG also has a number of both long- and short-term standards that do not correspond to any EPA standards. The FRG has a long-term standard for fine particulates ($\leq$10 μm mean particle size diameter) and nitrogen monoxide (NO) with no corresponding EPA standard. The FRG also has short-term standards for fine particulates ($\leq$10 μm), NO_2, and NO without any corresponding EPA standards for comparison. The FRG, on the other hand, has no standard for ozone to compare with the EPA standard of 235 $\mu g/m^3$ as a maximum hourly value per calendar year.

1.3 EMISSION STANDARDS AND REGULATIONS

Combustion units are subject to enforcement procedures based on the Federal Immission Control Act. The regulations have been promulgated as a series of ordinances (BImSch). Those pertaining to fuel combustion sources are as follows:

- *1.BImSchV (1979)*: addresses firing (combustion) installations not subject to licensing.

- *3.BImSchV (1975)*: limits the sulfur content of gas-oil and diesel fuels to 0.3 wt% beginning in January 1979 and to 0.15 wt% in the future.

- *4.BImSchV (1975)*: establishes that gas-firing installations (all types of gaseous fuels) with a thermal input capacity of $\leq$100 MW ($\leq$341 x 10^6 Btu/h) and other installations with a capacity of $\leq$1 MW ($\leq$3.41 x 10^6 Btu/h) are subject to licensing. The capacity is based on an entire site, not on single units. Licensing is expected to be extended to gas-fired installations with a thermal input capacity of $\leq$10 MW (34 x 10^6 Btu/h).

- *13.BImSchV (1983)*: sets emission standards for large combustion installations, i.e., gas-fired installations with a thermal input capacity of $\leq$100 MW ($\leq$341 x 10^6 Btu/h) and other installations with a thermal input capacity of $\leq$50 MW ($\leq$171 x 10^6 Btu/h). Specific measures include:

  - Emission limitations on the substances involved in acid rain, such as sulfur dioxide (SO_2), nitrogen oxides (NO_x),* hydrogen chloride, and hydrogen fluoride.

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*The FRG and U.S. ambient air quality standards are stated in terms of NO_2. The term NO_x specifically denotes any combination of NO and NO_2 that is emitted by a source. The reason why NO is regulated as a source emission is because it is readily converted to NO_2 in the atmosphere.

- Emission limitations on persistent toxic and carcinogenic components of particulate matter (PM), including heavy metals, and

- Emission reduction regulations for existing installations. For example, most power plants must either be retrofitted with flue gas desulfurization (FGD) devices to meet a standard of 400 mg/m^3 by 1988 or be shut down by 1983 after a maximum of 30,000 h of remaining full-load operation time.

In addition, the TA Luft sets emission standards and licensing procedures for installations of particular environmental significance. It specifically covers:

- Immission (ambient) standards for the most important air pollutants,

- Emission limits for air pollutants and types of installations, reflecting the state-of-the-art technology,

- Procedures for monitoring and evaluating immissions and emissions,

- Methods for calculating required stack heights, and

- Procedures authorizing new regulations for existing installations.

In Tables 1.2-1.6, air pollutant emission standards for the large fuel combustion sources covered by 13.BImSchV[1] are surveyed and compared with EPA new source performance standards (NSPS) for fossil-fuel-fired steam generators. Among the many differences that hinder a rigorous comparison are two that deserve special mention. The first is that the FRG emission limitations apply to the entire plant capacity at a given site (e.g., the combined capacity of all units at a power station), while the NSPS apply to each individual steam-generating unit with a rated capacity in excess of 250 x 10^6 Btu/h. The second important difference is that the FRG emission standards are specified as concentrations (i.e., mg/m^3) and have been converted to an approximate fuel input basis (i.e., lb/10^6 Btu). The factors used for this conversion assume a generalized volume of combustion air per unit of fuel-specific fossil fuel energy input to the boiler, which in turn determines the flue gas volume on a fuel-specific energy input basis. Although the conversion factors account for the variance in combustion air requirements among solid, liquid, and gaseous fuels, general assumptions have been made about other parameters within each fuel class, such as the fuel and combustion air moisture contents, combustion air temperature, and boiler design. The FRG standards assume that compliance cannot be achieved by dilution of the exhaust gas stream.

Table 1.2 shows that the emission limits for PM are generally more stringent than the NSPS emission limit of 0.1 lb/10^6 Btu for fossil-fuel-fired steam generators, but are generally less stringent than the NSPS electric utility steam generator limit of 0.03 lb/10^6 Btu. Since the FRG emission limitation applies to the collective plant capacity at a site, individual boilers that are new (i.e., installed after 1983) are subject to the same collective limit at a specific plant as existing boilers there. Thus, individual

TABLE 1.2 FRG Emission Limits versus U.S. NSPS: PM and Heavy Metals (for FRG plants with a thermal input capacity of ≥50 MW, or ≥171 x 10^6 Btu/h)

			FRG Emission Limits[a,b,c]			
					% of NSPS for Steam Generators	
Pollutant	Fuel Type	Plant Type	mg/m^3	$lb/10^6$	NSPS Units Built after 1971[d]	NSPS NSPS Utility Units Built after 1978[e]
PM	Solid					
	All	New	50	0.049	49	163
	Lignite	Existing[f]	80	0.078	78	260
	Others	Existing[f]	125	0.122	122	407
	Liquid (all)	New	50			
		Existing[f]	50-100	0.043-0.086	43-86	143-287
Heavy metals[g]	Solid (all but coal and wood)	New	0.5	0.0049	-	-
		Existing[f]	1.5	0.0015	-	-
	Liquid					
	Specified oils[h] with Ni > 12 ppm and nonspecified fuels	All	2	0.0017	-	-
	Other	All	-	-	-	-

[a]Related to an O_2 content (dry, 1013 mbar, 0°C) in flue gases of 3% for liquid fuels, 5% for solid fuels with liquid slag-off, 6% for solid fuels with dry slag-off, and 7% for fluidized bed combustion and grate firings.

[b]Continuous monitoring required for O_2 and CO at all installations and for PM at those fired with solid or liquid fuels (daily averages within limit, 97% of 30-min averages within 120% of limit, all 30-min averages within 200% of limit). For heavy metals, monitoring must be by measurement every 3 yr (at least three measurements, all within the limit). These requirements must be met by existing installations (except those using specified oils; see Ref. 6) by July 1985.

[c]The FRG limits are expressed as an exhaust gas concentration (mg/m^3) at 1 bar pressure, 15°C, and 12% CO_2 and were converted to an approximate fuel input basis ($lb/10^6$ Btu [ng/J]) using the following conversion factors: (1) 15,645 $ft^3/10^6$ Btu (420 m^3/GJ) for solid fuel and (2) 13,783 $ft^3/10^6$ Btu (370 m^3/GJ) for liquid fuel. Existing units with a remainder use of 30,000 h of full-load operation must comply with the limits by July 1988.

[d]For fossil-fuel-fired units rated >250 x 10^6 Btu/h for which construction began after Aug. 17, 1971. The PM emission limit is 0.1 $lb/10^6$ Btu.

[e]For fossil-fuel-fired utility units rated >250 x 10^6 Btu/h for which construction began after Sept. 18, 1978. Comparison is made only with the PM emission limit, which is 0.03 $lb/10^6$ Btu. However, the NSPS also require uncontrolled emission reductions of 99% for solid fuel and 70% for liquid fuel.

[f]The FRG emission limit depends on the boiler type and/or plant size.

[g]That is, arsenic, cadmium, chromium, cobalt, lead, and nickel.

[h]See Ref. 6.

TABLE 1.3 FRG Emission Limits versus U.S. NSPS: SO_2 from Solid Fuels

Plant Type	Plantwide Capacity: MW_{th}	Plantwide Capacity: 10^6 Btu/h	FRG Emission Limits[a,b,c]: mg/m^3	FRG Emission Limits[a,b,c]: lb/10^6 Btu	% of NSPS for Steam Generators[d]: NSPS Units Built after 1971[e]	% of NSPS for Steam Generators[d]: NSPS Utility Units Built after 1978[f]
New except FBC	50-100	171-341	2000, 2500[g]	1.96, 2.45[g]	163 204	327 408
	>100-300	>341-1024	2000 and 40% residual emission[h]	1.96 and 40% residual emission[h]	163	327
New FBC	50-300	171-1024	400 or 25% residual emission[h]	0.39 or 25% residual emission[h]	33	65
Existing (limited time)	≥50	≥171	2500, 3200[g]	2.45, 3.13[g]	204 261	408 522
New and existing[j]	>300	>1024	400 and 15% residual emission[h,j]	0.39 and 15% residual emission[h,j]	33	65

[a]Related to an O_2 content (dry, 1013 mbar, 0°C) in flue gases of 5% for solid fuels with liquid slag-off, 6% for solid fuels with dry slag-off, and 7% for FBC and grate firings.

[b]Continuous monitoring required for SO_2 at installations fired with solid fuels (daily average within limit, 97% of 30-min averages within 120% of limit, all 30-min averages within 200% of limit). These requirements must be met by existing installations by July 1985.

[c]Limits are expressed as an exhaust gas concentration (mg/m^3) at 1 bar pressure, 15°C, and 12% CO_2 and have been converted to an approximate fuel input basis (lb/10^6 Btu [ng/J]) using a conversion factor of 15,645 ft^3/10^6 Btu (420 m^3/GJ). Existing units with a remainder use of >30,000 h of full-load operation must comply with the limits by July 1988.

[d]Comparison is based on emission limits only, not on the additional requirements of percentage control of residual emissions by the FRG or of uncontrolled emissions by NSPS.

[e]For fossil-fuel-fired units rated >250 x 10^6 Btu/h for which construction began after Aug. 17, 1971. The SO_2 emission limit is 1.2 lb/10^6 Btu for coal or coal/wood residue combustion.

[f]For fossil-fuel-fired utility units rated >250 x 10^6 Btu/h for which construction began after Sept. 18, 1978. The SO_2 emission limits are (1) for solid and solid-derived fuel, 1.2 lb/10^6 Btu with 90% reduction of potential uncontrolled emissions or 0.6 lb/10^6 Btu with 70% reduction of such emissions, (2) for solvent-refined coal, 1.2 lb/10^6 Btu with 85% reduction of potential uncontrolled emissions, and (3) for noncontinental anthracite, 1.2 lb/10^6 Btu with no requirement for reducing potential uncontrolled emissions.

[g]Exception limit allowed 1 yr for coal and 6 mo for oil if no low-sulfur fuel is available and the stack height meets certain requirements (on application).

[h]Residual emission is defined as the ratio of the sulfur content in flue gas to that in fuel.

[i]Installations with a remainder use of >10,000 h of full-load operation by April 1993 must meet the same standard after that time as for new plants. When the remainder use is ≤ 10,000 h of full-load operation, the limit is set according to the existing license.

[j]For solid fuels with a high or extremely variable sulfur content, the limit is 0.64 lb/10^6 Btu (or 650 mg/m^3) with the maximum reduction rate by FGD.

TABLE 1.4 FRG Emission Limits versus U.S. NSPS: SO_2 from Liquid and Gaseous Fuels

Fuel Type	Plantwide Capacity: MW_{th}	Plantwide Capacity: 10^6 Btu/h	Plant Type	FRG Emission Limits[a,b,c]: mg/m^3	FRG Emission Limits[a,b,c]: $lb/10^6$ Btu	% of NSPS for Steam Generators[d]: NSPS Nonutility and Certain Utility Units Built after 1971[e] or 1978	% of NSPS for Steam Generators[d]: Certain NSPS Utility Units Built after 1978[f]
All liquid fuels	50-100	171-341	New	1700, 3400[g]	1.47, 2.93[g]	184 366	735 1465
	50-300	171-1024	Existing (limited time)[h]	2500, 3400[g]	2.16, 2.93[g]	270 366	1080 735
Gas oil ≤ 0.3 wt % sulfur or emission limit	>100-300	>341-1024	New	1700 and 40% residual emission[i]	1.47 and 40% residual emission[i]	184	735
	>300	>1024	New and existing	400[h] and 15% residual emission[i,j]	0.345[h] and 15% residual emission[i,j]	43	173
Liquid petroleum gas (LPG)	>100	>341	New	5	0.004	0.4	1.89

[a]Related to an O_2 content (dry, 1013 mbar, 0°C) in flue gases of 3%.

[b]Continuous monitoring required for SO_2 at installations fired with liquid fuels (daily average within limit, 97% of 30-min averages within 120% of limit, all 30-min averages within 200% of limit). For LPG, monitoring must be by measurement every 3 yr (at least three measurements, all within limit). These requirements must be met by existing installations by July 1985.

[c]The FRG limits are expressed as an exhaust gas concentration (mg/m^3) at 1 bar pressure, 15°C, and 12% CO_2 and have been converted to an approximate fuel input basis ($lb/10^6$ Btu [ng/J]) using the following conversion factors: 13,783 $ft^3/10^6$ Btu (370 m^3/GJ) for liquid fuels and 11,175 $ft^3/10^6$ Btu (300 m^3/GJ) for gaseous fuel. Emission limits must be met by July 1988 by installations with a remaining use of >20,000 h of full-load operation.

[d]Comparison is based on emission limits only, not on any additional percentage control requirements.

[e]For fossil-fuel-fired units rated >250 x 10^6 Btu/h for which construction began after Aug. 17, 1971, and fossil-fuel-fired utility units for which construction began after Sept. 18, 1978. The SO_2 limit is 0.8 $lb/10^6$ Btu for liquid fuels fired in both utility and nonutility units and for gaseous fuels in utility units built after 1978. For liquid-fuel-fired utility units built after 1978, there is also a 90% reduction in uncontrolled emissions for continental plants.

[f]For fossil-fuel-fired utility units rated >250 x 10^6 Btu/h for which construction began after Sept. 18, 1978, and that burn liquid and gaseous fuel and meet an SO_2 emission limit of 0.2 $lb/10^6$ Btu.

[g]Exception limit allowed 1 yr for coal and 6 mo for oil if no low-sulfur content fuel is available and the stack height meets certain requirements (on application).

[h]See note i to Table 1.3.

[i]Residual emission is defined as the ratio of the sulfur content in flue gas to that in fuel.

[j]For liquid fuels with a high or extremely variable sulfur content, the limit is 0.56 $lb/10^6$ Btu (650 mg/m^3) plus the maximum reduction rate by FGD.

TABLE 1.5 FRG Emission Limits versus U.S. NSPS: NO_x from Solid Fuels

Plantwide Capacity			FRG Emission Limits[a,b,c]		% of NSPS (in lb/10^6 Btu) for Steam Generators			
MW_{th}	10^6 Btu/h	Plant Type	mg/m^3 [d]	lb/10^6 Btu[d]	0.5[e]	0.6[f]	0.7[g]	0.8[h]
50-300	171-300	New liquid slag-off	1800 (400)	1.76 (0.39)	352 (78)	293 (65)	251 (56)	220 (49)
		New dry slag-off	800 (400)	0.78 (0.39)	156 (78)	130 (65)	111 (56)	98 (49)
		Existing dust-firing liquid slag-off	2000 (1300)	1.96 (1.27)	392 (254)	327 (212)	280 (181)	245 (159)
		Existing dust-firing dry slag-off	1300 (650)	1.27 (0.64)	254 (128)	212 (107)	181 (91)	159 (80)
		Other existing	1000 (650)	0.98 (0.64)	196 (128)	163 (107)	140 (91)	123 (80)
>300	>1024	New liquid slag-off	1800 (200)	1.76 (0.20)	352 (40)	293 (33)	251 (29)	220 (25)
		New dry slag-off	800 (200)	0.78 (0.20)	156 (40)	130 (33)	111 (29)	98 (25)
		Existing dust-firing liquid slag-off	2000 (200)	2.00 (0.20)	400 (40)	333 (33)	286 (29)	250 (25)
		Existing dust-firing dry slag-off	1300 (200)	1.27 (0.20)	254 (40)	212 (33)	181 (29)	159 (25)
		Other existing	1000 (200)	0.98 (0.20)	196 (40)	163 (33)	140 (29)	123 (25)

[a]Related to an O_2 content (dry, 1013 mbar, 0°C) in flue gases of 5% for solid fuels with liquid slag-off, 6% for solid fuels with dry slag-off, and 7% for FBC and grate firings.

[b]Continuous monitoring required for NO_x at installations fired with solid fuels (daily average within limit, 97% of 30-min averages within 120% of limit, all 30-min averages within 200% of limit). These requirements must be met by existing installations with a remaining use of >30,000 h by July 1985.

[c]The FRG limits are expressed as an exhaust gas concentration (mg/m^3) at 1 bar pressure, 15°C, and 12% CO_2 and have been converted to an approximate fuel input basis (lb/10^6 Btu) using a conversion factor of 15,645 $ft^3/10^6$ Btu (420 m^3/GJ). Emission limits for existing units must be met as soon as possible.

[d]Limits in parentheses were set by the Conference of German Ministers for the Environment to be applied in licensing processes or achieved by retrofitting existing installations. Best available control technology required in each case (see Ref. 1).

[e]Limit for utility units >250 x 10^6 Btu/h built after Sept. 18, 1978, burning coal-derived fuels, subbituminous coal, or shale oil.

[f]Limit for (1) all units rated >250 x 10^6 Btu/h built after Aug. 17, 1971, burning lignite or lignite/wood residue (as of Dec. 1976) and (2) utility units rated >250 x 10^6 Btu/h built after Sept. 18, 1978, burning lignite, bituminous, anthracite, and other solid fuels.

[g]Limit for units rated >250 x 10^6 Btu/h built after Aug. 17, 1971, burning coal or coal/wood residue.

[h]Limit for units rated >250 x 10^6 Btu/h burning >25% lignite mined in North or South Dakota or Montana in the following cases: (1) cyclone-fired units built after Aug. 17, 1971, and (2) slag-trap furnace utility units built after Sept. 18, 1978.

TABLE 1.6 FRG Emission Limits versus U.S. NSPS: NO_x from Liquid and Gaseous Fuels

		Plantwide Capacity		FRG Emission Limits[a,b,c]		% of NSPS (in lb/10^6 Btu) for Steam Generators		
Fuel	Plant Type	MW_{th}	10^6 Btu/h	mg/m^3[d]	lb/10^6 Btu[d]	0.2[f,g]	0.3[h,g]	0.5[i,g]
Liquid	New	50-300	171-1024	450	0.39	-	130	78
				(300)	(0.26)	-	(87)	(52)
	Existing	50-300	171-1024	700	0.60	-	200	120
				(450)	(0.39)	-	(130)	(78)
	New	>300	>1024	450	0.39	-	130	78
				(150)	(0.13)	-	(43)	(26)
	Existing	>300	>1024	700	0.60	-	200	120
				(150)	(0.13)	-	(43)	(26)
Gaseous	New	100-300	341-1024	350	0.25	125	-	50
				(200)	(0.14)	(70)	-	(28)
	Existing	100-300	341-1024	500	0.35	175	-	0
				(350)	(0.25)	(125)	-	(50)
	New	>300	>1024	350	0.25	125	-	50
				(100)	(0.07)	(104)	-	(14)
	Existing	>300	>1024	500	0.35	175	-	70
				(100)	(0.07)	(104)	-	(14)

[a]Related to an O_2 content (dry, 1013 mbar, 0°C) in flue gases of 3% for liquid and gaseous fuels.

[b]Continuous monitoring required for NO_x at installations fired with liquid fuels and at those fired with gaseous fuels if they are >400 MW_{th} (1365 x 10^6 Btu/h) (daily average within limit, 97% of 30-min averages within 120% of limit, all 30-min averages within 200% of limit). These requirements must be met by existing installations by July 1985.

[c]The FRG limits are expressed as an exhaust gas concentration (mg/m^3) at 1 bar pressure, 15°C, and 12% CO_2 and have been converted to an approximate fuel input basis (lb/10^6 Btu [μg/J]) using the following conversion factors: 13,783 $ft^3/10^6$ Btu (370 m^3/GJ) for liquid fuel and 11,175 $ft^3/10^6$ Btu (300 m^3/GJ) for gaseous fuel. Emission limits for existing units must be met as soon as possible.

[d]Limits in parentheses were set by the Conference of German Ministers for the Environment to be applied in licensing processes or achieved by retrofitting existing installations. Best available control technology required in each case (see Ref. 1).

[e]Comparison is based on emission limits only, not on the additional requirements of percentage control of uncontrolled emissions by NSPS utility steam generators.

[f]Limit for units rated >250 x 10^6 Btu built after Aug. 1971 or utility units built after Sept. 18, 1978, burning gas or gas/wood residue.

[g]Utility units rated >250 x 10^6 Btu must also reduce potential uncontrolled emissions by 25% for gaseous fuels and 30% for liquid fuels.

[h]Limit for units rated 250 x 10^6 Btu built after Aug. 17, 1971, or utility units built after Sept. 18, 1978, burning oil or oil/wood residue.

[i]Limit for utility units rated >250 x 10^6 Btu built after Sept. 18, 1978, burning coal-derived liquids or gaseous fuels.

boilers can have emission limits greater or less than the plantwide limit as long as the overall plantwide emissions are in compliance. This condition is applicable to all the FRG pollutant emission limitations. However, for SO_2 and NO_x (Tables 1.3-1.6), a distinction is made between existing and new plant capacity, so that existing sources must meet a collective emission limit different from that set for new source capacity.

Table 1.3 summarizes the FRG emission limits for SO_2 from combustion units at a plant site when solid fuel is burned. These limits are a function of rated plant capacity, whether it is new (since 1983) or existing and whether it consists of conventional boilers or fluidized bed combustion (FBC) units. In most instances, the FRG regulations for SO_2 establish both a specific emission limit (lb/10^6 Btu) and a required percentage reduction of residual SO_2 emissions (see footnote h in Table 1.3). Therefore, even if low-sulfur solid fuel is used that would meet the emission limit without controls, controls would still have to be employed to meet the percentage residual emission reduction. A similar regulatory concept is embodied in the U.S. NSPS, which specify both an emission limit and a requirement to reduce uncontrolled (potential) SO_2 emissions by a given percentage.

Table 1.3 indicates that, on a strictly Btu basis, FRG plantwide regulations are less stringent than the NSPS for conventional boiler capacity of less than 300 MW (1024 x 10^6 Btu/h). However, on a strictly Btu basis, the utility boiler NSPS are less stringent than the FRG plant site emission limit for plant capacity greater than 300 MW. The utility boiler NSPS allow about three times the emissions allowed under the FRG regulations. Similarly, the industrial boiler NSPS allow about 1.5 times the emissions allowed under the FRG regulations. Not only is the FRG limitation more stringent for large-boiler-capacity plants, but it is applicable to existing as well as new capacity. Therefore, the collective emission limit for both existing and new capacity at a plant site must be in compliance; if existing capacity cannot comply by July 1988 (see footnote c of Table 1.3) and new capacity is planned before 1988, then the new capacity must meet an even more stringent emission limit to compensate for any existing capacity not in compliance.

The FRG emission limits for SO_2 from liquid- and gaseous-fuel-fired boiler plants are summarized in Table 1.4. As in the case of solid fuel combustion, the limits are a function of total plant capacity and distinguish somewhat between new and existing boiler capacity. For large plants (i.e., total boiler capacity > 341 x 10^6 Btu/h), sources must meet an emission limit as well as a percentage reduction of residual SO_2 emissions, so that compliance cannot be achieved simply by using a low-sulfur fuel oil. A significant exception is that low-sulfur (≤0.3 wt% sulfur) fuel can be substituted for gas oil (equivalent to No. 2 distillate in the United States) in order to comply with the emission limit. As in the case of solid fuel, for plants where liquid fuel is burned, the regulations become significantly more stringent when the plant site capacity exceeds 1024 x 10^6 Btu/h, both in terms of the emission limit and the percentage reduction of residual emissions. Existing large liquid-fuel combustion sources must comply with these regulations by 1988. However, sources with a collective capacity of ≤1024 x 10^6 Btu/h may comply with a less stringent limitation until 1993, when they must meet the new-source limitation. Therefore, existing sources with capacities between 171 and 1024 x 10^6 Btu/h are allowed to meet a relatively relaxed limitation for approximately 10 years and must then be either retired or upgraded to the new-source level of control.

Table 1.4 indicates that, on the basis of pounds emitted per Btu, FRG regulations are less stringent than NSPS except for (1) large new- and existing-source capacity (i.e., $>1024 \times 10^6$ Btu/h) that burns liquid fuel and (2) new-source capacity that burns gaseous fuel (existing sources that burn gaseous fuel are not specifically covered in the FRG limitations). However, large liquid-fuel-burning capacity in the FRG can avoid all SO_2 control by burning gas oil (equivalent to No. 2 distillate oil) with a sulfur content of not more than 0.3 wt%.

In Table 1.5, the FRG emission limitations for NO_2 from solid fuel combustion are summarized for plant thermal input capacity of $\geq 50 \times 10^6$ Btu/h. As with the SO_2 emission limits, the FRG limitations for NO_2 become more stringent for plant capacity of $>1024 \times 10^6$ Btu/h. Within each plant capacity range, the limitations are a function of boiler design and age (i.e., new or existing). The most significant difference in the NO_2 limits between existing and new boiler capacity has to do with the requirement for best available control technology (see footnote d in Table 1.5), which is applied on a case-by-case basis as part of the source licensing (i.e., permit) process. A comparison between FRG and NSPS emission limitations indicates that the NSPS are consistently more stringent for both existing and new source capacity except when the use of best available control technology is required by the FRG licensing process.

Table 1.6 summarizes the FRG limitations for NO_2 emissions from combustion of liquid and gaseous fuels. As with the solid fuel combustion case, the NO_2 regulations are a function of the size and age (i.e., new or existing) of the plant capacity. For both large and small plant capacity, the FRG emission limits are less stringent than the NSPS except when best available control technology is required as part of the licensing process for individual sources. However, the NSPS limitation of 0.5 lb/10^6 Btu for coal-derived liquid and gaseous fuels is consistently less stringent than FRG limitations except for existing liquid-fuel-fired sources when the best available technology is not applicable.

When reviewing the emission standards in Tables 1.2-1.6, the reader should give special attention to the following four points that are auxiliary to the determination of source compliance:

- Standards are of little value if they are not monitored. As in the case of NSPS, most German standards for large firing (combustion) installations are monitored by continuous measurement. The daily averages must be within the limit, 97% of the 30-min averages must be within 120% of the limit, and all 30-min averages must be within 200% of the limit.

- The new German ordinance for large firing installations (13.BImSchG) has introduced standards for plants already in operation, since a substantial reduction of, for example, SO_2 emissions can only be achieved by reducing the emissions of existing installations, as well as regulating the emission limits for future installations.

- The emission limits are maximum values. Application of state-of-the-art emission control is required by the Federal Immission Control Law in each case. Concerning NO_x emissions, this principle is explicitly emphasized in all regulations because the technology has been evaluated as developing more rapidly than in other cases.

- Normally, German emission standards only prescribe an emission limit, and it is up to the operator of an installation to meet that limit. However, in the case of large installations, a maximum residual emission is also prescribed for SO_2 that can only be met by the use of FGD systems. This strategy is due to the recognition that the quantity of low-sulfur fuel is limited. This fuel should be used by preference in smaller installations where FGD systems are economically less viable. Large installations can meet the limits by desulfurizing a larger portion of the flue gas stream instead of using low-sulfur fuel. The application of a maximum residual emission limit is also embodied in U.S. NSPS.

2 AIR QUALITY, ACID DEPOSITION, AND FOREST DAMAGE

In recent years, a new damage syndrome has affected a number of tree species in the FRG. Known as *neuartige waldschäden* (new or novel kind of forest damage), this syndrome includes such symptoms as premature defoliation and dieback leading to death. Damage was first noted on silver fir (Abies alba) in the early 1970s and then on Norway spruce (Picea abies). Similar damage to silver fir has been noted on occasions over at least the last two centuries, but the present outbreak, which became more serious after 1976,[7] differs in that the damage is more intensive, persistent, and severe.[8] Damage to other species has been reported only since 1980.[9] The damage to Norway spruce significantly worsened in 1982 and 1983 in the Black and Bavarian Forests. Outside major forest areas, the decline of Norway spruce started abruptly in late autumn 1982.[7]

In the past few years, forest damage has increased very rapidly. Surveys by the Federal Ministry for Food, Agriculture, and Forestry show that the proportion of forest area with symptoms in West Germany grew from 8% in 1982 (representing approximately 560,000 hectares, or 1.4 million acres) to 35% in 1983 and 52% in 1984. In each successive annual survey, both the diversity of symptoms and the number of affected species have increased. The 1984 survey (see Table 2.1) indicates an approximate doubling of forest damage since 1983 to hardwood species such as beech and oak. As indicated in Table 2.1, most of the affected area fell in the slightly damaged category (10-20% foliage loss) during 1983 and 1984. However, in 1984, the percentage of area with moderate to severe damage increased from 18% to 80%.

Three main hypotheses have been proposed to explain forest dieback in West Germany, as well as in Central Europe.[11,12] These hypotheses relate to acid rain, ozone, and stress. A fourth hypothesis, involving ammonium, has been recently published in the literature.[13] All four hypotheses involve air pollutants as possible factors contributing to forest decline.

The acid rain hypothesis implicates SO_2 and NO_x, whereas the ozone hypothesis suggests that ozone and the subsequent photochemical oxidants produced in the atmosphere are key causative agents of the damage. One reason cited in support of this hypothesis is that the symptoms of forest damage have been found throughout the nation, including many rural areas that are remote from any major source of pollutants such as SO_2 and that therefore exhibit low to extremely low concentrations of SO_2 (as well as PM). However, correlations have been found between increasing elevations and increasing intensity of damage, which suggest that the factors of greatest importance may be ozone and length of fog exposure. With regard to silver fir and Norway spruce, which are the most important tree species involved in forest decline, it is theorized that ozone in combination with (acid) rain and fog play a key role.[1] The stress hypothesis postulates that all of the air pollutants in combination are participating in an overall stress environment that is affecting the production of carbohydrates in leaves, thereby decreasing the vitality of both roots and leaves.

According to the ammonium hypothesis, the increase of available nitrogen in air and precipitation during the last decade has changed the nitrogen conditions in the

TABLE 2.1 Foliar Damage to Tree Species in the FRG, 1983-1984

Tree Species	Area Affected in 1984: Total 10^6 ha	10^6 acres	% with Damage[a]: All Damage Categories	Moderate to Severe Damage[c]	% Change in Areas with Damage, 1983-84[b]: All Damage Categories	Moderate to Severe Damage[c]
Beech	0.631	1.559	50	12	92	168
Fir	0.152	0.376	87	57	16	18
Oak	0.269	0.665	43	9	187	327
Pine	0.866	2.140	59	21	32	87
Spruce	1.477	3.650	51	21	24	86
Others	0.303	0.749	31	8	82	-5
Total	3.698	9.138	50	18	47	80

[a]Damage classifications are based on the percentage foliage loss in the affected area, as follows: 0-10%, healthy; 11-20%, lightly damaged; 21-60%, sick; 61-99% very sick; 100% dead.

[b]Based on the percentage area damage documented in the 1983 survey.

[c]Moderate to severe damage comprises all trees with ≥21% foliage loss.

Source: Ref. 12.

temperate forests of northern Europe, causing trees to become oversaturated with nitrogen. The increase in precipitated nitrogen has caused trees to grow too fast, forming large cells with a high volume. This condition results in trees that are easily attacked by wind, drought, and parasites. This hypothesis is more complex than the other hypotheses since nitrogen is also a nutrient and, in the form of ammonia or ammonium, is used as a fertilizer. The hypothesis suggests that ammonia/ammonium and the NO_x in the atmosphere participate in tree damage.[13]

One problem in examining all these hypotheses is that few long-term records of air quality exist, especially in those areas where novel forest decline is now observed. Table 2.2 summarizes and compares ozone data from several rural sites in the FRG and in the United States.[4] Of the German sites listed, Schauinsland and Brotjacklriegel lie in

TABLE 2.2 Ozone Concentrations at Rural Sites in the FRG and the United States

Location	Elevation (m)	Years of Measurement	Ozone Concentration ($\mu g/m^3$)[a] Annual Mean	Summer Mean[b]	Annual Maximum[c]	% of Summer Hours with Ozone >200 $\mu g/m^3$[c]
Germany						
Brotjacklriegel	1025	1980-83	64	85	143-195[d]	0-0.2[d]
Deuselbach	480	1980-83	59	76	162-290[d]	e
Feldberg	825	1975-78	59	81	220-230	0-1.7
Hohenpeissenberg	975	1971-83	61	75	166-260	e
Michelsberg	588	1976-78	50[d]	71	240-300	0.1-1.9
Schauinsland	1205	1980, 1982-83	84	100	231-311	1.0-4.7
Waldhof	75	1979-80, 1983	68	87	244-320	e
Wank	1780	1977-82	63	73	120-158	e
Wendelstein	1832	1977-82	57[d]	70	e	e
United States						
California						
Rim Forest	1725	1968-72	e	e	1160	33.7-45.1
Whittaker Forest	1640	1976-80	e	e	244[d]	0.9-3.2[d]
Virginia						
Big Meadows	1040	1979-81	74	86	180	e
Rocky Knob	950	1977-79	86	104	209-300	e
Pinnacles	e	1977-78	93	105	207-216	e
Indiana/Wisconsin (7 sites)	e	1978-79	e	e	e	0-3.3

[a]Source: Ref. 14. Values listed there in parts per billion and per million have been converted to micrograms per cubic meter, taking account of the changes in atmospheric pressure with altitude.

[b]Summer values are calculated for the period April to September.

[c]The range is based on values obtained in different summers.

[d]Values were not recorded for the whole period of measurement.

[e]Not given in Ref. 14.

the areas with the greatest severity of forest damage. The U.S. sites are in areas where forest damage has occurred and the atmosphere is characterized by high ozone concentrations. The ozone concentrations recorded at Rim Forest in the San Bernardino Mountain (close to Los Angeles) are by any standards very high. Aside from the Rim Forest area, ozone concentrations tend to be higher at the U.S. sites than at most of the German sites except for Schauinsland.

3 EMISSION TRENDS

The FRG Federal Environmental Agency has developed some air pollution emission projections for electricity production in 1995 based on enforcement of the air pollution regulations promulgated since 1980.[1] The emission regulations assume that electricity generation will follow the trend specified in the Federal Energy Program (third revision, annex).[15] Electricity generation in 1980 and projections for 1995 are summarized in Table 3.1.

The Federal Energy Program specifies an increase of electricity production of 52% over the 15-yr period of 1980-1995. During this period, the percentage of total gross electricity production by fossil fuels is expected to decrease by 34%. This decrease is due to the significant increase in electricity production by nuclear and some renewable energy sources. Total electricity generation by bituminous (hard) coal is projected to increase from 111 TWh/yr in 1980 to 157 TWh/yr in 1995, but all other fossil fuels are expected to produce less total electricity in 1995 than in 1980. The total electricity production from fossil fuels is expected to remain basically unchanged over the 15-yr period.

TABLE 3.1 Fuel Shares of Projected FRG Electricity Production[a]

Fuel Type	% Share of Total Electricity Production			Fossil-Fuel-Produced Electricity (% of total electricity produced)		
	1980	1995	% Change	1980	1995	% Change
Nonfossil fuels[b]	20	47	135	-	-	-
Fossil fuels						
Gaseous fuel	16	6	-63	20.0	11.3	-44
Fuel oil	8	2	-75	10.0	3.8	-62
Lignite	26	17	-35	32.5	32.1	-1
Bituminous coal	30	28	-6	37.5	52.8	41
Total	80	53	-34	100.0	100.0	-

[a]Based on total electricity generation in 1980 of 369 TWh/yr and on projected production of 562 TWh/yr in 1995 (a 52% increase). In 1980, fossil-fuel-produced electricity was 295.2 TWh/yr and is projected to be 279.9 TWh/yr by 1995 (a 0.9% increase).

[b]Includes nuclear and renewable energy sources.

Source: Ref. 1.

Table 3.2 summarizes the estimated impact of current FRG air pollution regulations on 1995 emissions from electricity production, based on projected 1980 emissions. It is estimated that emissions of PM, SO_2, and NO_x (specifically NO_2) will decrease significantly due to the imposition of more-stringent controls. Emissions of hydrocarbons (HC) and carbon monoxide (CO) will increase, primarily due to the replacement of gas by coal.

In Figs. 3.1 and 3.2, FRG and U.S. trends in NO_x and SO_2 emissions are compared, based on data compiled by the Organization for Economic Cooperation and Development.[16] In both figures, the pollutant emission data are normalized to a base of 100 in 1970 and span a 13-yr period from 1970 to 1983 (data were not available for the FRG in 1983). As Fig. 3.1 indicates, both countries experienced a downward trend in SO_2 emissions, which became more significant in 1979. The rate of decrease was greater in the United States before 1979 and greater in the FRG after 1979. As Fig. 3.2 indicates, NO_x emissions increased overall in both countries between 1970 and 1983. In both countries, the increase was steady until 1979, though it occurred at a greater rate in the FRG. In 1979, the trend stabilized and slightly reversed in both countries. The decrease in NO_x emissions after 1979 appears more pronounced in the United States than in the FRG.

TABLE 3.2 Projected Impact of FRG Air Pollution Regulations on Emissions from Electricity Production in 1995

	Pollutant Emissions (10^3 metric tons/yr)														
	1980					1995					% Change, 1980-1995				
Fuel Type	PM	SO_2	NO_x[a]	HC	CO	PM	SO_2	NO_x[a]	HC	CO	PM	SO_2	NO_x[a]	HC	CO
Gaseous fuels	-	-	117	0.2	0.2	-	-	20	0.3	0.7	-	-	-83	50	250
Fuel oil	7	200	39	1.8	0.7	3	40	-	0.6	0.2	-60	-80	-100	-67	-71
Lignite	47	680	156	3.0	10.1	29	160	90	3.2	10.4	-38	-77	-42	7	3
Bituminous coal	93	810	468	3.4	18.0	44	220	120	5.1	26.7	-53	-73	-74	50	48
Total	147	1690	780	8.4	29.0	76	420	230	9.2	38.0	-48	-75	-75	10	31

[a]Specifically, NO and NO_2.

Source: Ref. 1.

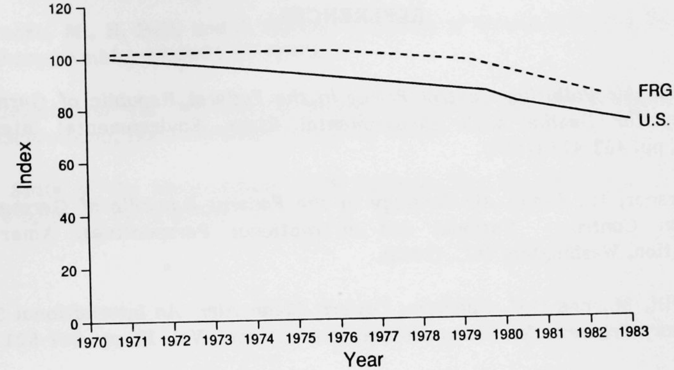

FIGURE 3.1 U.S. and FRG Trends in SO_2 Emissions

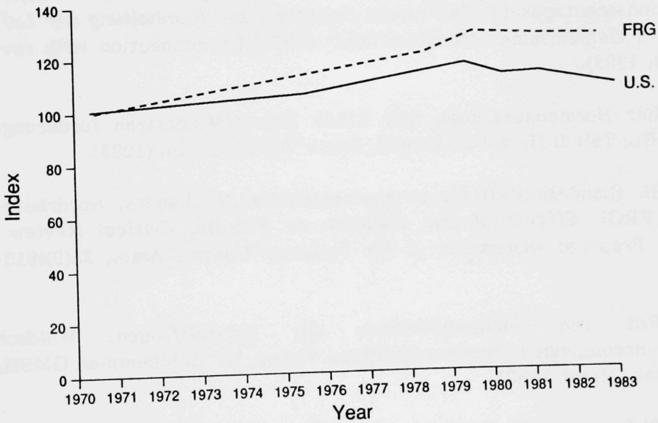

FIGURE 3.2 U.S. and FRG Trends in NO_x Emissions

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